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6 GROUND WATER

6.1 PURPOSE AND PROBLEM DEFINITION

6.1.1 Purpose

The purpose of the ground-water sampling was to conduct a limited focus investigation of the potential chemical impact of former normal, live-fire range training operations on ground water. This investigation consisted of installing eight monitoring wells and sampling the ground water near and/or within four impact areas, Impact Field 3W, Impact Field 5.3E, the Delta Impact Area, and Impact Field 7.5CF. A screening level human health risk assessment based on USEPA methods was conducted using the data collected from the ground-water samples. The data from this assessment and from assessments of other select ranges will be compiled to represent the condition of similarly situated ranges throughout the Army.

6.1.2 Problem Statement

Principal study questions were developed for ground water as part of the data quality objective (DQO) development. The questions are as follows:

- Are explosive compounds present in the ground water?
- Are metals present in the ground water at levels that substantially exceed the upgradient or background concentrations?
- Do detected concentrations exceed maximum contaminant levels (MCLs) or Health Advisories (HA)?
- Do detected concentrations pose an unacceptable health risk to future receptors?

6.2 REGIONAL SETTING

6.2.1 Physiography

JPG is located within rural areas of Jefferson, Jennings, and Ripley Counties, Indiana, which are located in the Muscatatuck Regional Slope of the Till Plain Section of the Interior Lowlands Physiographic Province. The Muscatatuck Regional Slope is characterized by till deposits capping a rolling limestone plateau and crossed by deep rocky valleys (USACE, 1991). The region has a westerly slope of approximately 400 feet over 25 miles or 0.17°. The slope is controlled by the regional dip of underlying bedrock. Generally, river valleys in the Muscatatuck Regional Slope are deeply entrenched along joints and fractures zones in the bedrock, and commonly make near-right angle turns (Fenelon & Greeman, 1994).

The southern two-thirds of JPG is relatively flat; the northern third is more rolling, with relatively steep bluffs along many of the major streams. Generally, the land surface at JPG slopes from east to west. Along the eastern boundary of JPG, elevations range from about 925–940 feet above mean sea level (msl). Elevations along the western boundary vary from about 835–850 feet above msl. Relief is greatest along stream channels, where it may exceed 100 feet (TetraTech NUS, 2000). Six almost parallel stream corridors flow across JPG in a generally

west-southwesterly direction. Each stream has well-developed drainage and consists of numerous tributaries. With the exception of the two most southern streams, drainages have cut into underlying limestone and formed steep banks (USACE, 1991).

6.2.2 Regional Geology

Located on the western flank of the Cincinnati Arch, a broad structural feature that separates the Illinois and Appalachian Basins, JPG lies within an area characterized by young glacial till plains of the Illinoian glacial period. The till deposits are composed predominantly of silts and clays with minor amounts of gravel and rock fragments. These deposits have an average thickness of 25 feet but in some areas thicknesses of 50 feet is common. At JPG the till deposits are generally not present in the incised stream valleys where bedrock has been breached (Earth Technology, 1994). Till deposits are underlain by carbonate units from the Ordovician, Silurian, and Devonian Periods. The carbonate units dip west-southwest at about 20 feet per mile (Earth Technology, 1994).

In the northern portion of JPG, Ordovician-aged limestones are exposed in the incised valleys formed by Otter Creek and Graham Creek. The oldest exposed unit is the Black River, Middle Ordovician Limestone. The Black River Limestone is fine grained and thickens to the south. The Black River Limestone underlies the Trenton Limestone. The Trenton Limestone is fine to medium-grained, includes extensive dolomite, and thins toward the south. Overlying the Trenton Limestone are interbedded shales and limestones of the Middle to Late Ordovician Maquoketa Group (USACE, 1991).

In Jennings County, Silurian-aged limestones and dolomites can be grouped into an upper and lower sequence. Shale, that can be as much as 12 feet thick, separates the two sequences. The upper limestone sequence has been eroded along the extreme eastern boundary of Jennings County and from all of JPG. A fine-grained, thick-bedded dolomite unit, containing numerous chert nodules, forms a resistant protective cover for the lower sequence. The lower limestone sequence ranges in thickness from 60-120 feet (Earth Technology, 1994) and jointing is prominent (Greeman, 1981).

At JPG, the oldest of the Silurian carbonates is the Brassfield Limestone. The Brassfield is a compact crystalline limestone, which unconformably overlies Ordovician Units, and underlies the Salamonie Dolomite. The Salamonie Dolomite is a fine-grained, light gray, porous dolomite and dolomitic limestone. The Laurel Member of the Salamonie Dolomite is a hard, light-dark gray limestone with zones of porous brown limestone. The Laurel Member of the Salamonie Dolomite is the most widespread unit at JPG. The Salamonie Dolomite underlies the Louisville Limestone. The Louisville Limestone is described as a light gray to brown, fine-grained dolomite or dolomitic limestone (USACE, 1991).

The Devonian Shaly dolomite of the Muscatatuck Group underlies glacial till in a small area near JPG's southwestern boundary. Mineralization in the bedrock at JPG includes pyrite and galena in the Trenton Limestone and fluorite and galena in the Muscatatuck Group. Sphalerite is also found in most Ordovician, Silurian, and Devonian units underlying JPG (USACE, 1991).

6.2.3 Regional Hydrogeology

6.2.3.1 Glacial Deposits

The direction of ground-water flow in the glacial till is roughly the same as the surface water drainage, which is to the west-southwest over most of JPG. The matrix hydraulic conductivity of the tills at JPG range from 1.1×10^{-5} to 8.4×10^{-5} inches/second. Small-scale fractures and sand lenses within the till contribute to the higher hydraulic conductivity (SBCCOM, 2002). Much of the hydrogeological and geological information pertaining to JPG was collected from studies performed at sites located south of the firing line at JPG.

6.2.3.2 Bedrock

In the JPG vicinity, the Silurian and Devonian-aged bedrock units are aquifers. These aquifers are poor sources of ground water, with well yields of less than 25 to 50 gallons per minute (gpm) (Rust, 1994b). Most inadequate bedrock well yields were reported in areas where the upper limestone-dolomite sequence has been removed; leaving the dense, thick-bedded, lower limestone sequence. The permeability of the lower limestone sequence is low because the siliceous dolomite capping the lower sequence is resistant to dissolution along vertical fractures and horizontal bedding planes. The higher well yields of 50 gpm may be obtained from the lower sequence along lineaments and fracture traces in the zone of high permeability associated with most perennial streams in the area (Greeman, 1981).

The shallow bedrock aquifer is confined to semiconfined. In areas where the overlying till is not fractured, the bedrock aquifer appears to be confined. The bedrock aquifer is recharged by infiltration and precipitation concentrated along fractures within the glacial till and in areas where the creek channels lose water to the ground-water system (SBCCOM, 2002). Generally, ground-water flow in the shallow bedrock aquifer is to the west-southwest. Many bedrock features such as interconnecting joints, fractures, solution channels, and other influences could alter flow directions (Ebasco, 1990). Water-level elevation data from wells screened in bedrock at JPG, loosely mimic surface topography. In the vicinity of incised surface drainages, the potentiometric surface slopes toward streams at roughly the same gradient as the surface topography. Therefore, on a local scale, ground water in shallow bedrock tends to discharge to surface streams (SBCCOM, 2002).

6.2.4 Ground Water Use

There are no sole source aquifers on or in the vicinity of JPG (SBCCOM, 2002). Public and private utilities provide water services to practically all households in the rural area surrounding JPG. Most of the utilities' water supply is pumped from the city of Madison well field, which yields approximately 8.3 million gallons per day from the sand and gravel alluvial aquifer of the Ohio River Valleys. There are limited numbers of private wells in the area surrounding JPG (Ebasco, 1990).

6.3 RATIONALE OF SELECTED SAMPLING LOCATIONS AND SAMPLE ANALYSES

6.3.1 Sampling Design Rationale

As stated in section 6.2.3.1, the direction of ground-water flow in glacial till is roughly the same as the surface drainage. In the vicinity of incised surface drainages, the potentiometric surface in shallow bedrock tends to slope toward streams at roughly the same gradient as the surface topography (SBCCOM, 2002). Seven streams and their tributaries drain JPG, and bedrock exposures are present along many of the stream channels. Due to the size of JPG, the number of streams, the fact that some streams are incised, and because ground water in glacial till and shallow bedrock tend to discharge to surface drainages, there are probably multiple ground-water basins.

Due to the size of JPG, the presence of multiple ground-water basins, and budgetary constraints, one general area was examined to evaluate the potential impact of live-fire training operations on ground-water quality. The selected study area (Figure 6-1) is within or in close proximity to the Delta Impact Area. The selected area contains four discreet units; Impact Field 3W, Impact Field 5.3E, Impact Fields 5.6W and 7.5CF (both are within the Delta Impact Area north of Big Creek and are considered one unit), and the Delta Impact Area south of Big Creek. All units selected for ground-water evaluation lie within an area that was delineated as contaminated with high explosives in the *Archives Search Report (ASR) for Ordnance and Explosive Waste, Chemical Warfare Materials* (USACE, 1995).

Impact Field 3W was selected for ground-water evaluation based on its location southwest of the Delta Impact Area. Impact Field 5.3E was selected for evaluation because of its location east of the Delta Impact Area and between two other impact fields (6.4E and 4.5E), and its probable upgradient or sidegradient location relative to the Delta Impact Area.

Impact Fields 5.6W and 7.5CF were selected based on their probable location within a different ground-water basin, and because three monitoring wells [MW-9, MW-10, and MW-11 (Figure 6-2)] were located hydraulically downgradient and/or sidegradient from the impact fields. The monitoring wells were installed during previous characterization surveys and Environmental Radiation Monitoring (ERM) for depleted uranium (DU) in and near the Delta Impact Area.

The unit within the Delta Impact Area south of Big Creek was selected to help further define ground-water quality and ground-water conditions south of Big Creek. Four ERM wells located near the perimeters of the Delta Impact Area south of Big Creek were incorporated into this study. The ERM wells are MW-1, MW-2, MW-5, and MW-6 (Figure 6-2).

FIGURE 6-1 GROUND-WATER STUDY AREA

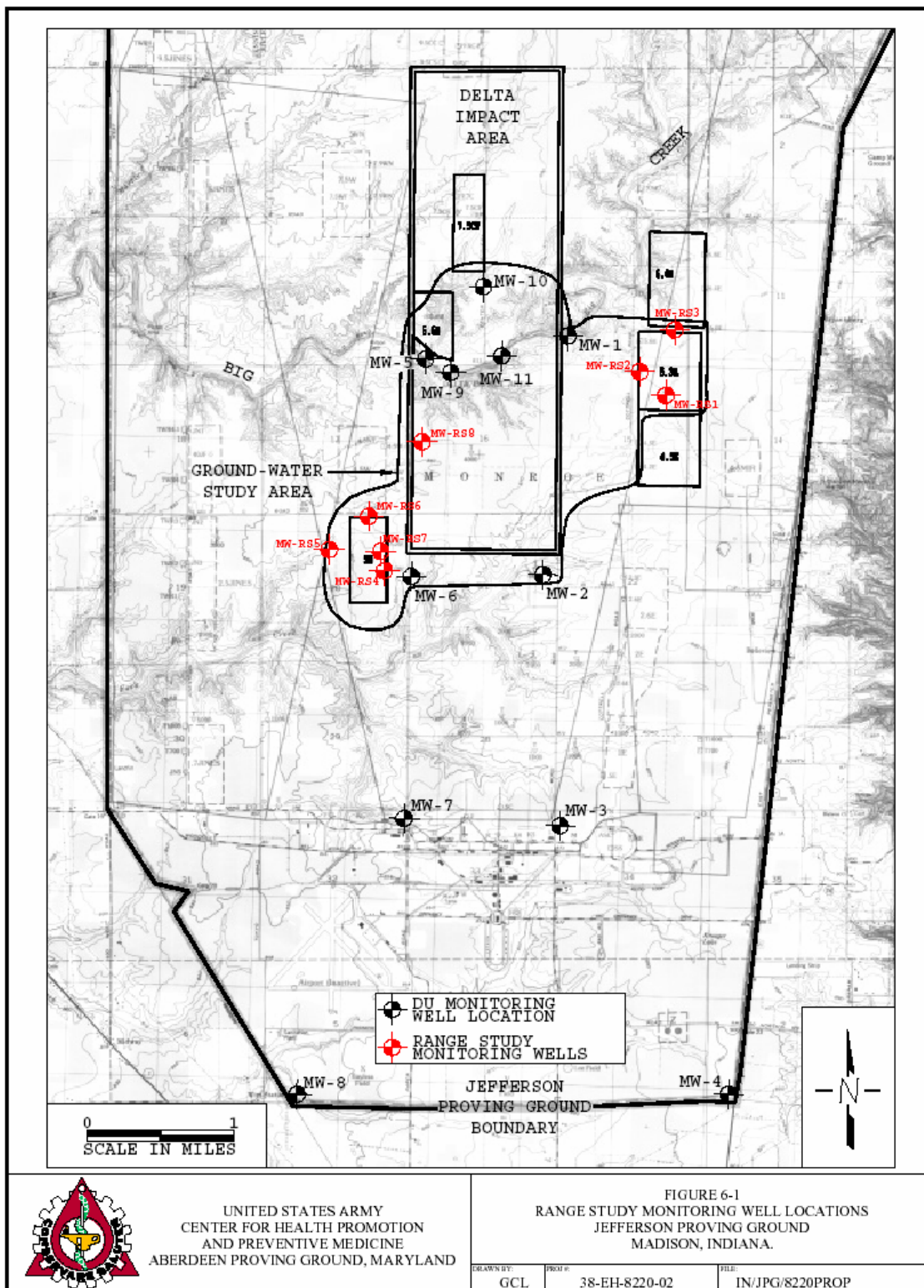
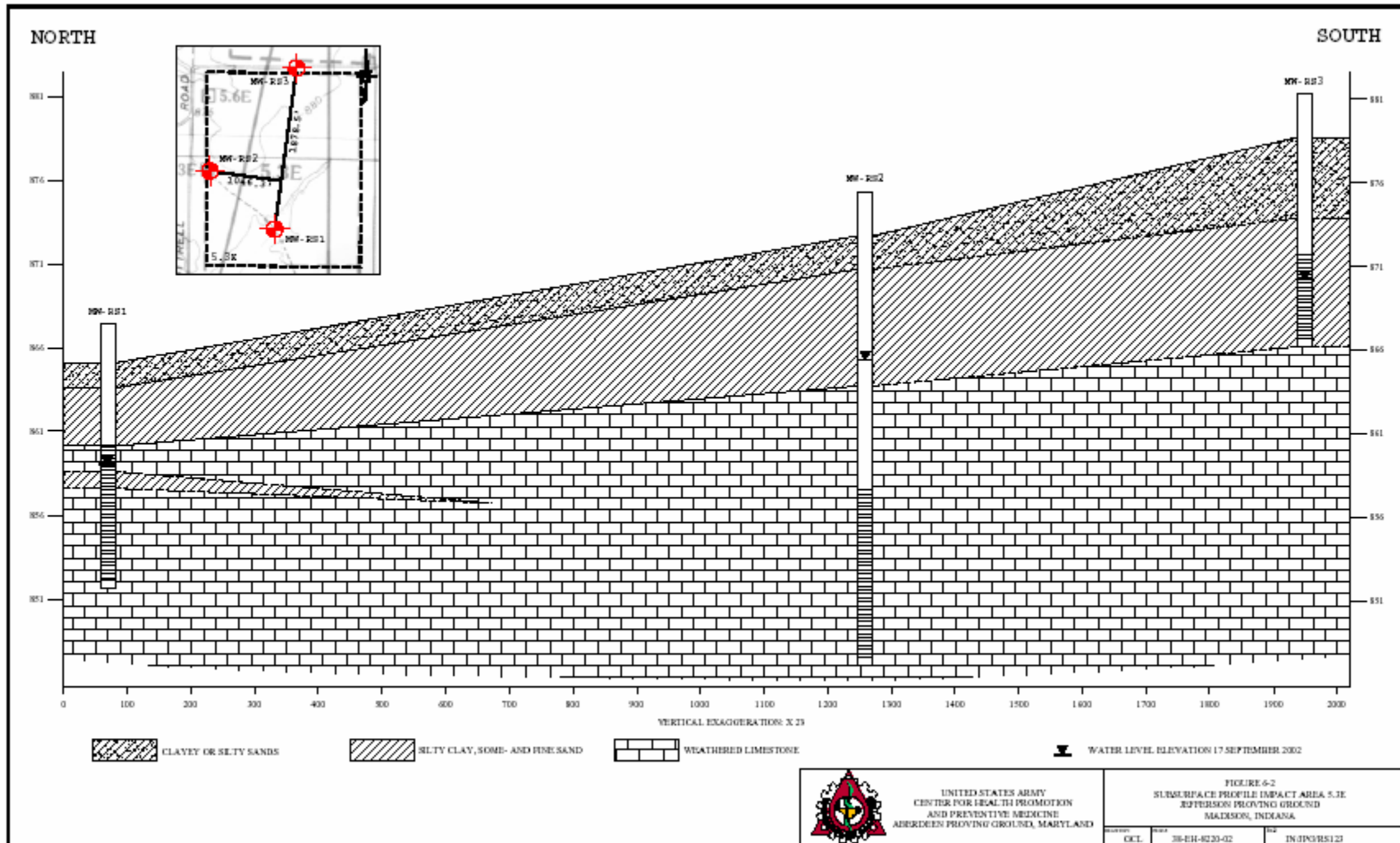


FIGURE 6-2 SUBSURFACE PROFILE IMPACT AREA 5.3E



6.3.2 Sampling Network

6.3.2.1 Monitoring Wells

Seven wells used in the DU monitoring program at JPG were incorporated into this range study. The wells are: MW-1, MW-2, MW-5, MW-6, MW-9, MW-10 and MW-11. Monitoring well MW-1 has two screened intervals; each screened interval is located in limestone. Monitoring wells MW-2, MW-5, and MW-9 are also screened in limestone. MW-6 is screened in a silty clay, and MW-10 and MW-11 are screened in glacial till.

Eight wells were installed by USACHPPM. Four wells were installed within or near the perimeter of Impact Field 3W. Three wells were installed near the perimeter or within Impact Field 5.3E. One well was installed inside the Delta Impact Area. Access to planned drilling locations shown in the QAPP was not feasible at some locations due to the presence of extensive UXO and topographical features, which precluded vehicle access to locations.

6.3.2.2 Springs

Three springs, each located near stream channels, were identified at JPG. Springs were sampled in conjunction with surface water sample collection. The spring sampling results are summarized in Section 8.4.8.

6.3.3 Analyses

Ground-water samples were collected from 15 wells (7 existing wells within and near the Delta Impact Area, and 8 monitoring wells installed by USACHPPM). The QAPP required that samples be analyzed for 15 explosive compounds (explosives and their degradation products), 14 metals (filtered and unfiltered), DU, perchlorate, hardness, and total dissolved solids. Analytes, analyses methods, reporting limits, and the significant contamination levels are listed in Tables 6-1, 6-2, and 6-3. The significant levels for the explosive compounds are indicated by the USEPA HA, and for the metals by the USEPA drinking water standards.

TABLE 6-1 CONTAMINANTS OF CONCERN IN GROUND WATER

Explosives	Acronym	CAS Number
Nitrobenzene	NB	98-95-3
2-Nitrotoluene	2-NT	88-72-2
3-Nitrotoluene	3-NT	99-08-1
4-Nitrotoluene	4-NT	99-99-0
Nitroglycerin (e)	NG	55-63-0
4-Amino-2,6-dinitrotoluene	4-A-2, 6-DNT	1946-51-0
1,3-Dinitrobenzene	1,3-DNB	99-65-0
2,4-Dinitrotoluene	2,4-DNT	121-14-2
2,6-Dinitrotoluene	2,6-DNT	606-20-2
2-Amino-4,6-dinitrotoluene	2-A-4, 6-DNT	355-72-78-2
Hexahydro-1,3,5-trinitro-1,3,5-triazine	RDX	121-82-4
1,3,5-Trinitrobenzene	1,3,5-TNB	99-35-4
Methyl-2,4,6-trinitrophenyinitramine	Tetryl	479-45-8
2,4,6-Trinitrotoluene	2,4,6-TNT	118-96-7
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	HMX	26-41-0
Metals	Acronym	CAS Number
Antimony	Sb	7440-36-0
Arsenic	As	7440-38-2
Barium	Ba	7440-39-3
Cadmium	Cd	7440-43-9
Calcium	Ca	7440-70-2
Chromium	Cr	7440-47-3
Copper	Cu	7440-50-8
Lead	Pb	7439-92-1
Manganese	Mn	7439-96-5
Magnesium	Mg	7439-95-4
Mercury	Hg	7439-97-6
Molybdenum	Mo	7439-98-7
Nickel	Ni	7440-02-0
Silver	Ag	7440-22-4
Uranium	U	7440-61-1
Vanadium	V	7440-62-2
Other Inorganics	Acronym	CAS Number
Perchlorate	ClO ₄	14797-73-0
Hardness	N/A	N/A
Total Dissolved Solids	TDS	N/A

N/A –Not Available

TABLE 6-2 EXPLOSIVES ANALYTE LIST, ANALYTICAL METHOD, REPORTING LIMITS, AND USEPA HEALTH ADVISORIES FOR GROUND WATER

ANALYTE	ANALYTICAL METHOD	LABORATORY SOP	PERFORMING LABORATORY	MRL (ug/L)	USEPA HEALTH ADVISORY
1,3,5-TNB	USEPA 8095M	CAD 13.2	USACHPPM-CAD	0.03	N/A
1,3-DNB	USEPA 8095M	CAD 13.2	USACHPPM-CAD	0.09	1.0 ²
2,4,6-TNT	USEPA 8095M	CAD 13.2	USACHPPM-CAD	0.03	2.0 ²
2,4-DNT	USEPA 8095M	CAD 13.2	USACHPPM-CAD	0.02	5.0 ^{1,3}
2,6-DNT	USEPA 8095M	CAD 13.2	USACHPPM-CAD	0.01	5.0 ^{1,3}
2-A-4,6-DNT	USEPA 8095M	CAD 13.2	USACHPPM-CAD	0.1	N/A
2-NT	USEPA 8095M	CAD 13.2	USACHPPM-CAD	0.09	N/A
3-NT	USEPA 8095M	CAD 13.2	USACHPPM-CAD	0.09	N/A
4-A-2,6-DNT	USEPA 8095M	CAD 13.2	USACHPPM-CAD	0.1	N/A
4-NT	USEPA 8095M	CAD 13.2	USACHPPM-CAD	0.09	N/A
HMX	USEPA 8095M	CAD 13.2	USACHPPM-CAD	3.0	400.0 ¹
NB	USEPA 8095M	CAD 13.2	USACHPPM-CAD	0.03	N/A
Nitroglycerin	USEPA 8095M	CAD 13.2	USACHPPM-CAD	0.09	N/A
RDX	USEPA 8095M	CAD 13.2	USACHPPM-CAD	0.1	2.0 ¹
TETRYL	USEPA 8095M	CAD 13.2	USACHPPM-CAD	0.5	N/A

NOTES:

MRL – Method Reporting Limit

N/A – Not Available

A health advisory is an estimate of acceptable drinking water levels for a chemical substance based on health effects information. It is not a legally enforceable Federal standard, but serves as technical guidance to assist Federal, State, and local officials. Unless otherwise noted, health advisories are for chronic lifetime exposures to a 70 kilogram adult that drinks about 2 liters of water per day. Health advisories will be used in this study for comparison purposes only.

1 – Source: U.S. Environmental Protection Agency, Summer 2000, Drinking Water Standards and Health Advisories, USEPA 822-B-00-001, Office of Water, Washington, D.C.

2 – Source: Roberts, Welford C., and William R. Hartley, editors, 1992, Drinking Water Health Advisories: Munitions, U.S. Environmental Protection Agency Drinking Water Health Advisories, Lewis Publishers, Boca Raton, Ann Arbor, London, Tokyo, 535 pp.

3 – This chemical is classified in USEPA cancer group B2. This means that there is sufficient evidence of carcinogenicity in animals and inadequate or no evidence in humans.

TABLE 6-3 METALS AND INORGANICS ANALYTE LIST, ANALYTICAL METHOD, REPORTING LIMITS, AND USEPA HEALTH ADVISORIES FOR GROUND WATER

ANALYTE	ANALYTICAL METHOD	LABORATORY SOP	PERFORMING LABORATORY	MRL (ug/L)	CURRENT DRINKING WATER STANDARDS ¹	
					MCL (ug/L)	SECONDARY STANDARDS
Antimony	USEPA 200.8	MET 21.4	USACHPPM-ASD	5	6	N/A
Arsenic	USEPA 200.8	MET 21.4	USACHPPM-ASD	4	10	N/A
Barium	USEPA 200.8	MET 21.4	USACHPPM-ASD	5	2000	N/A
Cadmium	USEPA 200.8	MET 21.4	USACHPPM-ASD	2	5	N/A
Calcium	USEPA 200.7	MET 41.5	USACHPPM-ASD	100	N/A	N/A
Chromium	USEPA 200.8	MET 21.4	USACHPPM-ASD	4	100	N/A
Copper	USEPA 200.8	MET 21.4	USACHPPM-ASD	5	N/A	1000
Lead	USEPA 200.8	MET 21.4	USACHPPM-ASD	4	15	N/A
Manganese	USEPA 200.8	MET 21.4	USACHPPM-ASD	4	N/A	50
Magnesium	USEPA 200.7	MET 41.5	USACHPPM-ASD	N/A	N/A	N/A
Mercury	USEPA 245.1	MET 17.4	USACHPPM-ASD	0.2	2	N/A
Molybdenum	USEPA 200.8	MET 21.4	USACHPPM-ASD	4	N/A	N/A
Nickel	USEPA 200.8	MET 21.4	USACHPPM-ASD	10	N/A	N/A
Silver	USEPA 200.8	MET 21.4	USACHPPM-ASD	2	N/A	100
Vanadium	USEPA 200.8	MET 21.4	USACHPPM-ASD	5	N/A	N/A
Uranium	USEPA 6020	RAD U_006.0	USACHPPM-RCCCD	20*	N/A	N/A
OTHER INORGANICS						
Perchlorate	USEPA 314.0	IC-EP314.0	DATAChem	2	N/A	N/A
Hardness	SM2340B	656	USACHPPM ASD	N/A	N/A	N/A
TDS	USEPA 160.1	GR-07-101	TriMatrix	25,000	N/A	N/A
Conductivity	Field	N/A	USACHPPM DEHE	None	N/A	N/A
DO	Field	N/A	USACHPPM DEHE	None	N/A	N/A
PH	Field	N/A	USACHPPM DEHE	None	N/A	N/A
Temperature	Field	N/A	USACHPPM DEHE	None	N/A	N/A
Turbidity	Field	N/A	USACHPPM DEHE	None	N/A	N/A

DO – Dissolved oxygen

MRL - Method Reporting Limit

N/A – Not Available

TDS – Total Dissolved Solids

*MCL is for uranium and will be changed to 30 µg/L effective 8 December 2003.

Metals samples preparation - USEPA 200.2

¹ Internet Web Page <http://www.epa/safewater/mcl.html>

6.4 FIELD ACTIVITIES AND SAMPLING PROCEDURES

6.4.1 Drilling and Monitoring Well Installation

USACHPPM mobilized personnel, a direct push probing machine, and a drill rig to JPG to conduct drilling operations and monitoring well installations. The direct push soil probing machine, mounted on the bed of a 1-ton truck, was used to complete downhole surveys and to advance direct push soil core samplers. The drill rig, a truck-mounted Mobile B-80, was used for hollow stem augering and air rotary drilling for the installation of monitoring wells. Drilling and well installation activities began on 13 August 2002 and were completed on 23 August 2002.

Explosive Ordnance Technologies, Inc. (EOTI) was contracted by USACHPPM to provide onsite UXO support. Personnel from EOTI were onsite with USACHPPM personnel during drilling, well installation and sampling, and surveying activities.

A geologist from USACHPPM monitored drilling operations, and collected borehole lithologic data and well construction information. Soil was logged in accordance with the Unified Soil Classification System. Water level data and any other pertinent remarks concerning drilling and well installation activities were also noted on boring logs and in the field notebook in accordance with Section 5.3.1 of the QAPP (USACHPPM, 2002). Boring and well construction logs are included in this report as Appendix E. Soil and rock cuttings generated during drilling were left at the drill site from which they were generated.

Eight borings (labeled MW-RS1 through MW-RS8, inclusive) were advanced for the installation of temporary monitoring wells (Figure 6-2). Several boring locations shown on Figure 5-3 and discussed in Section 5.2.11 of the QAPP were changed in the field because planned drilling locations were not accessible. Three borings, instead of the four specified in the QAPP, were installed along the perimeter of or within Impact Field 5.3E. The planned boring on the east side of Impact Field 5.3E was deleted because extensive UXO on the ground surface precluded vehicular access. Due to topographical features (steep slopes, ruts, and gullies) and the presence of UXO, the planned western and southern boring locations at Impact Field 3W were adjusted. Boring MW-RS5 was located as close to the western perimeter of Impact Field 3W as site conditions allowed. The southern section of Impact Field 3W was inaccessible to vehicles; so a boring location (MW-RS4) was selected at the southern most point of a former vehicle trail that crosses into Impact Field 3W. Because only three of the four borings planned for advancement in Impact Field 5.3E were completed, a boring (MW-RS8) was advanced inside the Delta Impact Area to aid in evaluating ground-water quality conditions in the area.

USACHPPM personnel purged and sampled 15 monitoring wells 17–23 September 2002. Purge and sample data were recorded on field forms (Appendix E). Water purged from monitoring wells was not containerized.

6.4.1.1 Surface and Downhole UXO Surveys

EOTI conducted a UXO surface sweep at each drilling location and the vehicular ingress/egress to each drill location. The UXO sweep was necessary to identify potential UXO on or near the surface, which might present a hazard to onsite workers. Magnetometers were used to locate metallic objects on the surface and in the shallow subsurface (within 4 feet of ground surface). UXO located on the surface was identified and marked for avoidance. Following surface UXO avoidance sweeps, the upper 2 – 3 feet of each boring was hand augered by EOTI personnel and a gradiometer was lowered into the hole to scan for metallic objects. Following hand augering, borings were advanced with a direct-push soil probing machine. Direct-push borings were advanced in 4-foot increments so a gradiometer could be lowered down the borehole to survey for metallic objects in the subsurface. UXO personnel requirements, procedures, and descriptions are provided in Section 5.2.2 and Annex A of Appendix K of the QAPP (USACHPPM, 2002). Although not required by the QAPP, soil core samples were collected from borings MW-RS2 – MW-RS8 to aid in describing the subsurface material.

6.4.1.2 Drilling Procedures

After direct-push soil borings were deemed clear of metallic objects, the drill rig was used to ream borings for the installation of monitoring wells. Borings were reamed/overdrilled with 7.25-inch outside diameter (OD) by 4.25-inch inside diameter (ID) hollow-stem augers (HSAs). Borehole depths were dependent on several factors including, downhole clearance depths for UXO avoidance, depth to auger refusal, or the presence of dry zones underlying saturated zones.

Auger refusal was encountered at 9 feet below ground surface (bgs) in boring MW-RS2. Due to auger refusal, air rotary drilling techniques were required to advance the boring to its total depth. A 5.6-inch diameter air hammer, attached to 4.5-inch air rods, was lowered through 10 feet of HSAs to advance the boring to its terminal depth.

Downhole equipment and the back of the drill rig were cleaned prior to use at each boring location. Cleaning consisted of the physical removal of soil, and rinsing with potable water and a power washer. Equipment was cleaned at select locations near, but outside, each impact area where borings were installed. Water used to rinse equipment was obtained from a fire hydrant on the south side of the firing line, and was transported to each impact field in a water tank mounted on a trailer.

6.4.1.3 Monitoring Well Construction Procedures

USACHPPM attempted to screen the uppermost ground water at each impact field. With the exception of MW-RS1 and MW-RS2, monitoring wells installed by USACHPPM were screened in the overburden. Although the screen of MW-RS1 was placed in limestone, the sand pack does extend into the overburden. Because the overburden at MW-RS2 ranged from moist-to damp-to dry, with moisture content decreasing with depth, the well was screened in weathered limestone. When the HSAs were at a depth of 8 feet in boring MW-RS2, the HSAs were pulled from the boring to check for the presence of ground water. After remaining open for approximately 1-1/2 hours no ground water was detected in boring MW-RS2 and drilling was resumed.

Monitoring wells were constructed through HSAs. This method was used to reduce sloughing in the borehole, and to ensure that all screens were properly centered for sand pack placement. At boring MW-RS2, the HSAs extended from above ground surface to approximately 9.5 feet bgs.

All wells were constructed of 2-inch ID, Schedule 40, flush-threaded, factory-wrapped, polyvinyl chloride (PVC) riser pipe and screen. Screens consist of 0.010-inch factory slotted pipe and range in length from 5 – 10 feet. Due to relatively shallow ground water and shallow boring depths at some locations, 10 feet of screen could not be set in each well and allow for an effective surface seal. Screen lengths were selected to screen across the greatest saturated interval while maintaining enough vertical space above the well screen so the sand pack could extend at least 1 foot above the screen, and a minimum 1.5-foot bentonite seal could be placed on the sand pack, with enough space remaining to set the protective casing without breaching the seal. Some 10-foot well screen sections were cut to shorter lengths in the field before well construction depending on subsurface conditions at a site. The screened interval in MW-RS2 was selected so there would be enough vertical space above the well screen and sand pack to seal the annular space below the contact of the overburden and limestone.

A well point, typically 0.5 feet in length, or a slip cap were placed at the bottom of each well screen. Slip caps were placed on the bottom of screens that were cut in the field. The PVC riser pipe extends from the top of the screen to approximately 2.5 – 3 feet above ground surface. Each well was fitted with a vented PVC cap. Well construction logs are contained in Appendix E and well construction details are summarized on Table 6-4.

An artificial sand pack was placed in the annular space around the well from the base of the borehole to at least 1 foot above the well screen. The sand pack in each well consists of commercially purchased silica sand. The sand pack was placed by pouring sand through the augers, and gradually withdrawing the augers in stages. The annular space above the sand pack was sealed with bentonite pellets. Bentonite pellets were poured from ground surface, through the augers and formed at least a 1.5-foot seal. Bentonite pellets were hydrated with distilled water.

The remaining annular space was grouted. An upright steel protective casing with a hinged, locking cap was installed over each PVC riser pipe and grouted into place. The protective casings extend to a depth of approximately 2 feet bgs. A drain hole was drilled into the protective casing near the ground surface.

TABLE 6-4 MONITORING WELLS CONSTRUCTION DETAILS

Well No.	Northing	Easting	Date Installed	Ground Surface Elevation (Ft msl)	TOC Elevation (Ft msl)	Total Depth (Ft bgs)	Screen Length (Ft)	Slot Size (in.)	Screen Interval (Ft msl)	Sand Pack Interval (Ft msl)	Seal Interval (Ft msl)	Open Interval Formational Material (Ft msl)
MW-RS1	503005.2707	577855.4394	20/Aug/02	865.1	867.43	13.5	8	0.010	851.6 - 859.6	851.6 - 860.8	860.8 - 862.2	limestone & clayey silt
MW-RS2	503847.0441	576944.9146	16/Aug/02	872.8	875.43	25.7	10	0.010	847.1 - 857.6	847.6 - 859.9	859.9 - 868.7-	limestone
MW-RS3	505381.7919	578161.3596	17/Aug/02	878.7	881.25	12.5	5	0.010	866.2 - 871.2	866.2 - 872.7	872.7 - 874	silty clay
MW-RS4	496416.5607	567877.9056	19/Aug/02	858.1	860.72	14.8	9	0.010	843.3 - 852.3	843.3 - 853.3	853.9 - 853.9	silty clay & fine sand
MW-RS5	497351.9896	565862.4473	18/Aug/02	851.2	853.72	13.1	8	0.010	838.1 - 846.2	838.1 - 847.4	847.4 -848.7	silty clay & fine sand
MW-RS6	498493.3647	567297.3022	18/Aug/02	857.9	860.17	14.8	9	0.010	843.1 - 852.5	843.1 - 853.9	853.9 -855.4	silty clay & sand
MW-RS7	467243.6429	567739.7984	19/Aug/02	859.2	861.72	12.5	5	0.010	846.7 - 851.7	846.7 - 854.2	854.2 - 855.7	silty clay & sand
MW-RS8	501278.9558	569046.8177	21/Aug/02	864.0	866.93	15.7	10	0.010	848.3 - 858.3	848.3 – 860.1	860.1 - 861.1	silty clay & sand
MW-1	504983.4695	573987.2719	06/Dec/83	851.7	853.49	33.2	4.8	0.006	818.5 - 823.3	818.5 - 848.49	848.49 -847.7	limestone
							4.8	0.006	838.6-843.420	“	“	limestone
MW-2	496877.0486	573990.6136	13/Dec/83	848.0	850.18	23.7	10	0.006	824.3 - 834.3	824.3 - 835.5	835.5 - 836.5	limestone
MW-5	504375.1632	568636.2430	07/Dec/83	801.6	804.05	33.4	10	0.006	768.2 - 778.2	768.2 - 779.6	779.6 - 780.6	limestone
MW-6	496603.1512	568641.3525	17/Dec/83	858.4	861.12	40	10	0.006	818.4 - 828.4	818.4 - 830.4	830.4 - 831.9	silty clay
MW-9	504716.6247	572005.9329	09/Sept/88	819.6	819.58	38.2	20	UK	781.4 - 801.6	781.6 - 801.6	801.6 - 804.6	limestone & shale
MW-10	506791.1421	571247.2907	18/Sept/88	860.8	865.75	41.3	20	UK	819.5 - 839.5	819.5 - 839.8	839.8 - 843.3	sandy to clayey silt
MW-11	504032.1293	570131.3331	19/Sept/88	809.4	809.56	41.9	30	UK	767.5 - 797.5	767.5 - 797.4	797.4 - 806.9	limestone & shale

Notes:
No. – number.
Ft msl – feet mean sea level.
Ft bgs – feet below ground surface.
TOC – Top of casing.
UK – Unknown.

6.4.1.4 ERM Wells

The seven existing wells incorporated into this range study were installed during the 1980's. Construction details are included in Table 6-4. Wells MW-1, MW-2, MW-5, and MW-6 were installed in 1983 by T.M Gates, Inc. These wells were constructed from PVC riser pipes and screens and were fitted with steel protective covers. Well caps and locks were missing from each well. The protective casing lids were also partially or completely open at each well allowing the introduction of vegetation and precipitation into the well pipes. Wells MW-9, MW-10, and MW-11 were installed in 1988 by ATEC Associates, Inc. These wells were all flush mounted and only MW-10 was fitted with a well cap and lock. Wells MW-9 and MW-10 were not capped, making the introduction of vegetation, debris, precipitation, and surface runoff into the wells possible. Although riser pipe and screen materials were not specified on boring and well installation logs, the riser pipes of MW-9, MW-10, and MW-11 were PVC.

6.4.1.5 Monitoring Well Development

Newly constructed wells were developed to remove fines associated with well installation, and to enhance hydraulic communication of the well screen with the formation material. Wells were developed by manually bailing and surging with decontaminated stainless steel bailers. Bailers were decontaminated in accordance with Section 5.4.1 of the QAPP. Ground water purged from wells was not containerized. Wells were developed until a minimum of three standing water columns was evacuated, or until the well was purged dry. The pH, conductivity, and temperature of purged ground water were measured periodically during well development and recorded on well development forms (Appendix E). Visual descriptions of turbidity were also recorded on well development forms. Prior to and after development, water level data were also collected.

6.4.1.6 Surveying

Classickle, Inc., professional surveyors licensed in the State of Indiana, surveyed the horizontal location and the elevation of the 15 monitoring wells sampled during this study. Elevations to the nearest 0.01 foot were provided for the reference mark at the top of each PVC riser pipe. The ground surface elevation was also surveyed at each well. Horizontal locations and elevation data were referenced on the Indiana State Plane East Zone and the North American datum 1927. Survey data are included on boring logs in Appendix E and on Table 6-4.

6.4.1.7 Water Level Measurements

The water level in each well was measured to the nearest 0.01 foot with a decontaminated water level indicator in accordance with Section 5.3.5.1 of the QAPP. Measurements were made from the reference mark on the top of the PVC riser pipe. Water levels are included in Table 6-5. The water level probe and cable were cleaned between uses following decontamination methodology presented in Section 5.4.1 of the QAPP.

TABLE 6-5 STATIC WATER LEVEL MEASUREMENT

Well No.	Date	Time	Water Level (btoc)	TOC Elevation (ft msl)	Water Elevation (ft msl)	Comments
MW-RS1	17-Sept-02	1140	8.36	867.43	859.07	
	23-Sept-02	1000	8.63	867.43	858.80	
MW-RS2	17-Sept-02	1125	10.04	875.43	865.39	
	23-Sept-02	1005	10.33	875.43	865.10	
MW-RS3	17-Sept-02	1119	11.00	881.25	870.25	
	23-Sept-02	950	11.47	881.25	869.78	
MW-RS4	17-Sept-02	1430	10.56	860.72	850.16	
	23-Sept-02	844	11.04	860.72	849.68	
MW-RS5	17-Sept-02	1345	10.65	853.72	843.07	
	23-Sept-02	908	11.28	853.72	842.44	
MW-RS6	17-Sept-02	1400	10.28	860.17	849.89	
	23-Sept-02	916	11.74	860.17	848.43	
MW-RS7	17-Sept-02	1450	8.99	861.72	852.73	
	23-Sept-02	856	9.59	861.72	852.13	
MW-RS8	17-Sept-02	---	NM	---	---	
	23-Sept-02	925	12.51	866.93	854.42	
MW-1	17-Sept-02	1104	13.59	853.49	839.9	
	23-Sept-02	1016	18.11	853.49	835.38	
MW-2	17-Sept-02	1045	13.35	850.18	836.83	
	23-Sept-02	1030	13.48	850.18	836.70	
MW-5	17-Sept-02	1330	17.45	804.05	786.6	
	23-Sept-02	930	17.2	804.05	786.85	
MW-6	17-Sept-02	1440	21.59	861.12	839.53	
	23-Sept-02	849	41.37	861.12	819.75	Not static
MW-9	17-Sept-02	1250	33.55	819.58	786.03	
	23-Sept-02	---	NM	---	---	Not static
MW-10	17-Sept-02	1240	9.88	865.75	855.87	
	23-Sept-02	---	NM	---	---	
MW-11	17-Sept-02	1315	30.62	809.56	778.94	
	23-Sept-02	---	NM	---	---	Not static

Notes:

btoc – below top of casing.

ft msl – feet mean sea level.

TOC – Top of casing.

NM – Not measured.

-- - No data.

6.4.2 Ground-Water Purging and Sampling Procedures

6.4.2.1 Ground-Water Purging and Sample Collection footnotes

Monitoring wells were purged to ensure that water representative of the ground-water system was collected for analysis. Wells were purged by one of the following methods; low-flow purging with a peristaltic pump or an electric submersible pump, or by bailing. Wells were purged following methodologies outlined in Section 5.3.5.2 of the QAPP. The selected purge method was based on one or more of the following; a low recharge rate, a short water column, a small well volume, depth, or other factor. Wells purged by pumping generally followed procedures outlined in the USEPA Region I Low Stress (low flow) Purging and Sampling Procedure for the Collection of Ground Water Samples from Monitoring Wells, July 30, 1996, revision 2. Tubing and bailers were dedicated to a single well and disposed of after a well was purged and sampled.

Monitoring wells MW-1, MW-2, MW-5, MW-10, MW-RS1, MW-RS2, MW-RS4, MW-RS5, MW-RS6, MW-RS7, and MW-8 were purged and sampled with a peristaltic pump. Due to a slow recovery rate, monitoring well MW-RS3 was purged with a factory cleaned Teflon[®] bailer and sampled the following day with a peristaltic pump. The intake of the peristaltic pump was set at the mid-point of the screen if the screen was completely below the water table, or at a depth equal to the middle of the water column within the well if the top of the water level was below the top of the screen. The peristaltic pump was fitted with a controller to regulate the flow rate (discharge). Low-flow procedures were followed during purging and sampling. Flow rates ranged from 180 milliliters per minute (mL/min) to 300 mL/min. Flow rates were recorded on Sampling Field Logs (Appendix E).

A multiprobe flowcell sampling system was used to monitor indicator parameters during well purging and/or sampling. Ground water was pumped through the intake tubing to the surface where it flowed into and through a 250-milliliter capacity cell fitted with probes that monitored pH, conductivity, temperature, and dissolved oxygen. An in-line bypass valve was located upstream of the flowcell to allow periodic withdrawal of water for turbidity measurements. The indicator parameters were monitored for stabilization. When the indicator parameters had stabilized, or 3-5 standing well volumes were purged, samples were collected directly from the tubing into the laboratory-supplied sample containers. Water samples were collected upstream of the flowcell to prevent cross-contamination between monitoring wells. Field parameters and other information relative to purging and sampling were recorded on Sample Field Logs (Appendix E). All tubing used with the peristaltic pump was disposed of after each use.

Monitoring wells MW-6 and MW-9 were purged with stainless steel bailers decontaminated in accordance to Section 5.4.1 of the QAPP. Bailers were used because each well had a very slow recovery rate and the depth to ground water was too great to use a peristaltic or whale pump. The static water levels in MW-6 and MW-9 on 17 September 2002 were 21.59 feet btoc and 33.6 feet btoc, respectively. The depth of well MW-6 was 42.5 feet btoc. The depth of MW-9 was 38.6 feet btoc. Monitoring well MW-6 was purged dry after one standing well pipe volume

[®] Teflon is a registered trademark for E.I. Dupont de Nemours & Company, Inc., Wilmington, Delaware.

(3.6 gallons) was evacuated. Monitoring well MW-9 was purged dry after approximately 3 standing well pipe volumes (2.5 gallons) were evacuated. Due to low water volumes in both wells, only two readings of field indicator parameters were obtained. The indicator parameters were measured by placing the pH, temperature, and conductivity probes directly into a beaker that contained purged water. Dissolved oxygen was not measured during purging because the flow through cell could not be used due to insufficient water volumes.

Water levels in MW-6 and MW-9 did not recover sufficiently over a 5-day period to provide enough water volume to collect a full sample set. The water level in MW-6 the day after purging was only 41.51 feet btoc, a recovery of approximately 1 foot. On 20 September 2002, a sample for explosives analysis was collected from MW-6. After filling the sample bottle the well was dry. On 22 September 2002, a sample for perchlorate analysis was collected from MW-6. After collection of the perchlorate sample the well was again dry. MW-9 was purged dry on 17 September 2002. On 22 September 2002, only 0.5 feet of standing water was measured in the well. The standing water (less than 1 liter) was collected for explosives analysis. Samples for the other analytical parameters were not collected from MW-9.

Samples from MW-6 were collected with a factory cleaned Teflon bailer. The sample collected from MW-9 was collected with the stainless steel bailer used during purging. Water contained in bailers during sampling was emptied directly into the appropriate, laboratory-supplied sample containers. The Teflon bailer and the line used to collect samples from each well was disposed of after each use.

Monitoring well MW-11 was purged and sampled with an electrical submersible pump. On 18 September 2002, the pump intake was set at the middle of the water column and the well was purged at a rate of approximately 300 mL/min. The water column was lowered to a depth equal to the pump intake. On 19 September 2002, the pump was turned on to purge the tubing extending from the pump to the surface, and to attempt to collect samples. The water column was lowered to the pump intake. The pump was then set at a depth of 40 feet btoc, approximately 2 feet from the bottom of the well. The water column was pumped at flow rates varying from 200 – 500 mL/min, and was pumped dry. On 20 September 2002, approximately 5 feet of water was standing in the well; the pump was turned on and samples for filtered metals, filtered mercury, and unfiltered mercury analysis were collected before the well was pumped dry. On 21 September 2002, samples for explosives, perchlorate, and total dissolved solids were collected for analysis. After collection of these samples, the well was dry and a sample for unfiltered metals analysis could not be collected. Field parameters were collected during purging on 18-19 September 2002. Because of the low water volume the field parameters were not measured during sample collection in an attempt to collect as much water as possible for laboratory analysis. A summary of samples submitted for laboratory analyses is provided in Table 6-6.

TABLE 6-6 SUMMARY OF GROUND-WATER SAMPLES COLLECTED FOR ANALYSES

Well Number	Explosives	TDS	Perchlorate	Total Metals	Total Hg	Dissolved Hg	Dissolved Metals
MW-RS1	X	X	X	X	X	X	X
MW-RS2	X	X	X	X	X		
MW-RS3	X	X	X	X	X	X	X
MW-RS4	X	X	X	X	X	X	X
MW-RS5	X	X	X	X	X		
MW-RS6	X	X	X	X	X	X	X
MW-RS7	X	X	X	X	X	X	X
MW-RS8	X	X	X	X	X	X	X
MW-1	X	X	X	X	X		
MW-2	X	X	X	X	X		
MW-5	X	X	X	X	X		
MW-6	X		X				
MW-9	X						
MW-10	X	X	X	X	X		
MW-11	X	X	X	X	X	X	

Notes:

TDS – Total dissolved solids.

Hg – Mercury.

6.4.2.2 Ground-Water Sample Filtering

Section 5.2.3 the QAPP required the collection of filtered samples for metals analysis. Due to low turbidity measurements during well purging, samples for filtered metals analysis were only collected if the turbidity of the ground water was greater than 5 nephelometric turbidity units (NTUs). Samples were filtered in the field by attaching an in-line, 0.45-micron, acrylic copolymer-pleated membrane filter housed in a polyethylene capsule to the outlet of the pumps' discharge tubing or to the outlet of a bailer.

6.4.2.3 Ground-Water Sample Preservation, Labeling, Storage, and Shipment

The USACHPPM Directorate of Laboratory Sciences (DLS) provided clean sample containers. All ground-water samples were placed into the appropriate laboratory-supplied sample containers. Nitric acid was added to samples collected for metals and mercury analysis immediately after sample collection. The pH adjustments were checked in the field by pouring a small volume of sample over a pH strip to ensure the pH was lowered to a pH of 2 or less.

Ground-water samples were labeled, documented, and handled in a manner consistent with Sections 8.1.3, 8.2, 8.3, and 8.5 of the QAPP. All samples were placed into ice-filled coolers after collection and preservation. At the end of each work day, samples were transferred to sample custodians for refrigeration and repackaging for shipment to the analytical laboratories.

6.4.3 Field Sampling Quality Control (QC)

To assure the validity and reliability of the sampling data, QC samples were collected as required by Section 5.3.5.7 of the QAPP. QC samples include equipment blank/field blanks, a blind duplicate sample, and cooler temperature blanks. The QAPP required that duplicate samples and equipment blanks be collected at a minimum frequency of 5 percent per parameter. The blind duplicate sample, labeled MW-RS9, was collected from monitoring well MW-RS7. An equipment blank was collected by pumping distilled water through new tubing attached to a peristaltic pump. Temperature blanks were supplied by the laboratory and were included in each cooler containing samples shipped to the analytical laboratory. The number of ground-water samples collected during this study, including QC samples, is summarized on Table 6-7.

TABLE 6-7 NUMBER OF GROUND-WATER AND QC SAMPLES

Analyte*	Analytical Method	Number of Normal Samples**	QC Samples***		Total
			Blind Duplicate	Field Blank	
Explosives	USEPA 8095M	15	1	1	17
Metals (Unfiltered)	USEPA 200.8	12	1	1	14
Metals (Filtered)	USEPA 200.8	7	1	0	8
Perchlorate	USEPA 314.0	14	1	1	16
Total Dissolved Solids	USEPA 160.1	13	1	1	15

Notes:

* See Table 6-1 for specific analytes of concern.

** Normal samples are non-QC samples collected from monitoring wells.

*** Duplicate samples and field blanks were collected on a frequency of 5% of normal samples.

6.4.4 Field Equipment Calibration Maintenance, Testing, and Inspection

The accuracy of the field measurements of pH, temperature, specific conductance, dissolved oxygen, and turbidity were addressed through pre-measurement calibrations and post-measurement verifications. Field instruments were checked daily for proper operation. The dissolved oxygen, pH, specific conductance, temperature, and turbidity meters were calibrated and inspected daily prior to use following guidelines detailed in Sections 5.5.1 and 5.5.2 of the QAPP. Calibrations were documented on field calibration forms (Appendix E). Post-measurement verifications were performed at the end of the sampling workday and documented in the field notebook. No maintenance was required on field instrumentation during the field program.

6.4.5 Investigation-Derived Wastes

Soil cuttings generated during drilling were spread on the ground near the boring from which the cuttings were generated. Ground water evacuated from each well during purging and sampling was discharged to the ground surface. Solid wastes such as rubber gloves and paper towels used during this study were placed in plastic bags and disposed as municipal solid waste.

6.5 GROUND-WATER INVESTIGATION RESULTS

6.5.1 Analytical Results

6.5.1.1 Explosives

No explosive compound was detected in any ground-water sample. Laboratory data sheets are included in Appendix B. DLS method CAD SOP 13.2 was used to analyze ground-water samples. A summary of the method reporting limits is provided in Table 6-8. Seven reporting limits for two compounds 1,3,5-TNB and 2Am46DNT were above the method reporting limits specified in Section 1 of the QAPP. Method reporting limits for 1,3,5-TNB (in samples from MW-9, MW-RS1, MW-RS4, MW-RS5, MW-RS7, and MW-RS8) and 2Am46DNT (MW-RS4) were raised due to interferences in the samples that could not be resolved on any of the analytical columns.

6.5.1.2 Perchlorate

Perchlorate was not detected in any ground-water sample. Samples were analyzed by USEPA Method 314.0; a summary of the method detection limits are presented in Table 6-9. Laboratory data sheets are included in Appendix B. All detection limits were below the 2 µg/L method reporting limit specified in Section 1 of the QAPP. The method detection limits for samples MW-5 and MW-11 (0.67 and 3.4 µg/L, respectively) are higher than the method detection limit of 0.337 µg/L for all other samples. The method detection limits for samples from MW-5 and MW-11 were raised since the samples had to be diluted because the samples' conductivities were above the established maximum conductivity threshold (MCT). MW-5 was diluted by a factor of two and MW-11 was diluted by a factor of 10 to bring the conductivities below the MCT.

6.5.1.3 Metals

The unfiltered sample results of the metals analyses are shown in Table 6-9. Laboratory data sheets are included in Appendix B. The filtered sample results of the metals analyses are shown in Table 6-10. When available, metals results are compared to the primary and secondary MCLs contained in the National Primary Drinking Water Regulations (USEPA, 2002). Metals that do not have an MCL are compared to mean background concentrations of metals in ground water south of the firing line.

TABLE 6-8 RESULTS OF EXPLOSIVES ANALYSES

Compound	USEPA Health Advisory µg/L	Method Reporting Limits Specified in QAPP	MW-1 µg/L	MW-2 µg/L	MW-5 µg/L	MW-6 µg/L	MW-9 µg/L	MW-10 µg/L	MW-11 µg/L	MW-RS1 µg/L	MW-RS2 µg/L	MW-RS3 µg/L	MW-RS4 µg/L	MW-RS5 µg/L	MW-RS6 µg/L	MW-RS7 µg/L	MW-RS9 (Duplicate Sample of MW-RS7) µg/L	MW-RS8 µg/L
Nitrobenzene	NHA	0.03	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030
2-Nitrotoluene	NHA	0.09	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090
3-Nitrotoluene	NHA	0.09	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090
4-Nitrotoluene	NHA	0.09	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090
Nitroglycerin	NHA	0.09	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090
1, 3-Dinitrobenzene	1.0	0.09	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090
2, 6-Dinitrotoluene	5.0	0.01	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
2, 4-Dinitrotoluene	5.0	0.02	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020
1, 3, 5-Trinitrobenzene	NHA	0.03	< 0.030	< 0.030	< 0.030	< 0.030	< 0.23*	< 0.030	< 0.030	< 0.060*	< 0.030	< 0.030	< 0.17*	< 0.15*	< 0.030	< 0.13*	< 0.030	< 0.10*
2, 4, 6-Trinitrotoluene	2.0	0.03	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030
RDX	2.0	0.1	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
4-Amino-2,6-dinitrotoluene	NHA	0.1	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
2-Amino-4,6-dinitrotoluene	NHA	0.1	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.15*	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Tetryl	400.0	0.5	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
HMX	NHA	3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0

Notes:

- NHA – No Health Advisory.
- <0.300 – indicates the compound was not detected at the indicated method reporting level.
- * - Reporting limit raised due to interference in samples that could not be resolved on any of the analytical columns.

TABLE 6-9 INORGANIC ANALYSES RESULTS OF UNFILTERED SAMPLES

Compound	Drinking Water Standard	Mean Back-ground	MW-1	MW-2	MW-5	MW-6	MW-9	MW-10	MW-11	MW-RS1	MW-RS2	MW-RS3	MW-RS4	MW-RS5	MW-RS6	MW-RS7	MW-RS8	MW-RS9 (D. S.)
Perchlorate			<0.337	<0.337	<0.67	<0.337	NA	<0.337	<3.4	<0.337	<0.337	<0.337	<0.337	<0.337	<0.337	<0.337	<0.337	<0.337
Metals																		
Antimony, (g/L	6P	30.0	<2.00	<2.00	<2.00	NA	NA	<2.00	NA	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00
Arsenic, (g/L	10 P	4.00	<1.00	3.69	1.12	NA	NA	<1.00	NA	7.42	<1.00	6.88	5.43	1.14	<1.00	2.02	1.06	<1.00
Barium, (g/L	2,000 P	263	48.4	154	82.4	NA	NA	245	NA	33.8	38.6	285	128	15.8	159	74.0	158	73.8
Cadmium, (g/L	5P	3.39	<1.00	<1.00	<1.00	NA	NA	<1.00	NA	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Calcium, (g/L	NS	96,041	111,000	81,900	157,000	NA	NA	88,700	NA	80,900	172,000	81,200	115,000	74,100	83,800	73,100	97,700	74,700
Chromium, µg/L	100 ^P	11.1	<2.00	<2.00	<2.00	NA	NA	<2.00	NA	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00
Copper, µg/L	1,300 ^{Su}	9.40	2.16	<2.00	<2.00	NA	NA	6.15	NA	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	2.06	<2.00	<2.00
Lead, µg/L	15 ^{Pu}	2.24	<2.00	<2.00	<2.00	NA	NA	<2.00	NA	<2.00	<2.00	2.44	<2.00	<2.00	<1.00	<2.00	<2.00	<2.00
Magnesium, µg/L	NS	39,516	29,700	36,200	56,700	NA	NA	34,200	NA	70,600	18,400	31,900	39,400	28,100	30,600	45,400	34,200	46,400
Manganese, µg/L	50 ^S	311.2	<2.00	17.8	15.4	NA	NA	19.4	NA	72.0	28.1	2,690	1,210	252	150	799	2,060	800
Mercury, µg/L	2 ^P	0.05	<0.200	<0.200	<0.200	NA	NA	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200
Molybdenum, µg/L	NS	26.4	<2.00	<2.00	<2.00	NA	NA	6.06	NA	7.63	3.64	22.2	16.6	8.36	<1.00	17.9	7.60	17.7
Nickel, µg/L	NS	17.8	<2.00	<2.00	<2.00	NA	NA	<2.00	NA	<2.00	<2.00	3.70	4.68	<2.00	2.18	3.34	15.4	3.19
Silver, µg/L	100 ^S	0.17	<1.00	<1.00	<1.00	NA	NA	<1.00	NA	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Vanadium, µg/L	NS	13.8	<1.00	<1.00	<1.00	NA	NA	<1.00	NA	<1.00	<1.00	2.55	1.78	1.18	<1.00	1.92	1.66	2.02
Zinc, µg/L	5,000 ^S	12.8	<100	<100	<100	NA	NA	<100	NA	<100	<100	<100	<100	<100	<100	<20	<100	<100
Uranium (Total), µg/L	30 ^{P*}	NS	0.632	1.15	0.430	NA	NA	2.42	NA	3.28	0.856	14.0	10.9	8.12	1.68	22.4	6.36	24.6
Uranium, U235/U238 ratio	NS	NS	0.00627	0.00713	0.00702	NA	NA	0.00720	NA	0.00724	0.00708	0.00727	0.00722	0.00720	0.00720	0.00725	0.00727	0.00725
Uranium ratio uncertainty	NS	NS	0.000190	0.000110	0.000450	NA	NA	0.000100	NA	0.0000900	0.00021	0.0000600	0.0000700	0.0000400	0.000100	0.0000500	0.0000400	0.0000500
Calculated Hardness, µg/L	NS	NS	399,000	354,000	626,000	NA	NA	362,000	NA	493,000	172,000	334,000	449,000	301,000	335,000	369,000	385,000	378,000
Total Dissolved Solids, µg/L	500,000 ^S		394,000	382,000	3,120,000	NA	NA	456,000	13,800,000	540,000	232,000	518,000	496,000	388,000	562,000	1,150,000	486,000	1,110,000

NOTES:

D.S. Duplicate sample, sample was collected from MW-RS7.

NA – Not analyzed.

NS - No drinking water standard.

P –Maximum Contaminant Level. National Primary Drinking Water Regulations, USEPA.

Pu – Primary MCL at point of use.

S – National Secondary Drinking Water Regulation or secondary standards, USEPA.

Su – Secondary MCL at point of use.

* Uranium MCL as of 8 December 2003

<0.300 – indicates the compound was not detected at the indicated method reporting level.

Due to inadequate water volume, samples were not collected from MW-6 and MW-9, and only mercury was collected from MW-11.

TABLE 6-10 INORGANIC ANALYSES RESULTS OF FILTERED SAMPLES

Compound	Drinking Water Standard	Mean Background	MW-11 Dissolved	MW-RS1 Dissolved	MW-RS3 Dissolved	MW-RS4 Dissolved	MW-RS6 Dissolved	MW-RS7 Dissolved	MW-RS8 Dissolved	MW-RS9 (D. S.) Dissolved
Metals										
Antimony, µg/L	6 ^P	30	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00
Arsenic, µg/L	10 ^P	4	6.24	7.40	7.97	5.47	<1.00	1.71	<1.00	1.83
Barium, µg/L	2,000 ^P	263	264	32.4	274	141	147	84.9	148	78.5
Cadmium, µg/L	5 ^P	3.39	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Calcium, µg/L	NS	96,041	343,000	71,200	78,500	111,000	85,100	73,700	95,800	72,700
Chromium, µg/L	100 ^P	11.1	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00
Copper, µg/L	1,300 ^{Su}	9.40	4.25	2.21	<2.00	<2.00	<2.00	2.00	<2.00	<2.00
Lead, µg/L	15 ^{Pu}	2.24	<2.00	<2.00	<2.00	<2.00	<200	<2.00	<2.00	<2.00
Magnesium, µg/L	NS	39,516	202,000	65,100	31,000	38,100	30,700	45,500	33,500	45,100
Manganese, µg/L	50 ^S	311.2	159	59.5	2,450	1,260	140	786	1,980	749
Mercury, µg/L	2 ^P	0.05	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200
Molybdenum, µg/L	NS	26.4	<2.00	7.80	16.8	17.6	<2.00	17.6	6.80	17.7
Nickel, µg/L	NS	17.8	2.79	<2.00	3.32	3.55	2.09	3.21	13.2	2.87
Silver, µg/L	100 ^S	0.17	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Vanadium, µg/L	NS	13.8	<1.00	<1.00	2.53	1.16	<1.00	1.92	<1.00	1.99
Zinc, µg/L	5,000 ^S	12.8	<100	<100	<100	<100	<100	<100	<100	<100
Uranium (Total), µg/L	30*	NA	0.254	3.30	12.0	10.4	1.69	21.4	5.86	21.8
Uranium, U235/U238 ratio	NS	NA	0.00608	0.00720	0.00724	0.00721	0.00727	0.00725	0.00721	0.00727
Uranium ration uncertainty	NS	NA	0.000240	0.0000500	0.0000600	0.0000700	0.000120	0.0000600	0.0000500	0.0000400
Calculated Hardness, µg/L	NS	NA	1,690,000	446,000	324,000	434,000	339,000	371,000	377,000	367,000

NOTES:

D.S. Duplicate sample, sample was collected from MW-RS7.

NA – Not analyzed.

NS - No drinking water standard.

P –Maximum Contaminant Level. National Primary Drinking Water Regulations, USEPA.

Pu – Primary MCL at point of use.

S – National Secondary Drinking Water Regulation or secondary standards, USEPA.

Su – Secondary MCL at point of use.

* Uranium MCL as of 8 December 2003

<0.300 – indicates the compound was not detected at the indicated method reporting level.

Due to inadequate water volume, samples were not collected from MW-6 and MW-9, and only mercury was collected from MW-11.

The mean background concentrations were derived from ground-water sample and analysis during several studies and investigations conducted by others south of the firing line. Three clusters of three wells each were installed south of the firing line to formulate a conceptual model for ground-water flow by collecting data from the wells with respect to regional variability in general ground-water chemistry, geology, and potentiometric head (Rust, 1994a). Two wells in each cluster are screened in bedrock, and the shallow well is screened at the bedrock-glacial till contact. All nine wells were sampled for general water chemistry parameters, including total metals, anions, pH, dissolved oxygen, and conductivity. Additionally, at each Remedial Investigation/Feasibility Study site south of the firing line, one well (thought to be upgradient) was selected and sampled for general water quality data. This provided general water quality data for any additional wells used in the evaluation of background water chemistry across the installation south of the firing line (Rust, 1994a). Analytical data from the background wells is summarized in Table 6-11. As shown on Table 6-11, the mean background concentrations for some metals are below the certified reporting limit.

Antimony, cadmium, chromium, mercury, silver, and zinc were not detected in any filtered or unfiltered sample collected during this range study. Arsenic was detected in unfiltered samples collected from five wells; all concentrations are below the primary MCL. Arsenic concentrations in filtered samples are also below the MCL and show close similarity to the arsenic concentrations in unfiltered samples. Barium was detected in all filtered and unfiltered ground-water samples. Barium concentrations are at least one order of magnitude below the primary MCL. Lead was only detected in the unfiltered sample collected from MW-RS3. The reported lead concentration, 2.44 µg/L, is less than the primary MCL of 15 µg/L.

Total uranium was detected in all filtered and unfiltered samples at concentrations below the primary MCL of 30 µg/L. Concentrations of total uranium in unfiltered samples range from 0.632 µg/L – 22.4 µg/L. The lowest total uranium concentrations (0.632 µg/L – 1.15 µg/L) are reported for wells screened in limestone. Total uranium results for unfiltered samples are similar to the filtered results. Filtered sample concentrations range from 0.254 µg/L – 21.4 µg/L. A U235/U238 uranium ratio of 0.00720 or less and within a measurement uncertainty of +/- 0.0001 is indicative of potential DU content with in sample. This ratio suggests the presence of some DU in the sample MW-1 unfiltered. The U235/U238 sample for MW-11 filtered sample is also less than the 0.000720 ratio but the measurement uncertainty is greater than 0.0001. The U235/U238 ratio in all other samples does not indicate the presence of DU (Falo, 2002).

Copper was detected in two unfiltered samples (MW-1 and MW-10) and in two filtered samples (MW-11 and MW-RS1) at concentrations ranging from 2.21 µg/L – 21.6 µg/L. The highest concentration is at least two orders of magnitude below the secondary MCL of 1,300 µg/L.

Manganese was detected in all samples with the exception of the sample collected from MW-1. Manganese concentrations in unfiltered samples collected from wells screened in bedrock only (wells MW-1, MW-2, MW-5, and MW-RS2) range from less than the detection limit to 28.1 µg/L. All manganese concentrations in these wells are less than the secondary MCL of 50 µg/L.

TABLE 6-11 METALS DATA FOR BACKGROUND MONITORING WELLS SOUTH OF THE FIRING LINE

	Number of Detections	Number of Samples	CRL	Low	High	MEAN
Unfiltered Metals						
Antimony, µg/L	0	9	60.0	30.0	60.0	30.0
Arsenic, µg/L	4	12	2.35	1.18	17.0	4.00
Barium, µg/L	12	12	2.82	34.5	967	263
Cadmium, µg/L	0	12	6.78	3.39	6.78	3.39
Calcium, µg/L	12	12	105	74,700	119,000	96,041
Chromium, µg/L	1	12	16.8	8.40	41.0	11.1
Copper, µg/L	0	12	18.8	9.40	18.8	9.40
Lead, µg/L	0	12	4.47	2.24	4.47	2.24
Magnesium, µg/L	12	12	135	18,600	59,700	39,516
Manganese, µg/L	12	12	9.67	63.1	1380	311.2
Mercury, µg/L	0	12	0.10	0.05	0.10	0.05
Molybdenum, µg/L	0	9	52.7	26.4	52.7	26.4
Nickel, µg/L	1	12	32.1	16.0	37.6	17.8
Silver, µg/L	0	12	0.333	0.17	0.333	0.17
Vanadium, µg/L	0	12	27.6	13.8	27.6	13.8
Zinc, µg/L	1	12	18.0	9.00	26.1	12.8
Filtered Metals						
Antimony, µg/L						
Arsenic, µg/L	4	12	2.35	1.175	15.70	3.71
Barium, µg/L	12	12	2.820	26.20	934.0	262.5
Cadmium, µg/L	0	12	6.780	3.390	6.780	3.39
Calcium, µg/L	12	12	105.00	72,500	119,000	96,858
Chromium, µg/L	0	12	16.80	8.400	16.80	8.40
Copper, µg/L	0	12	18.80	9.40	18.80	9.40
Lead, µg/L	0	12	4.470	2.235	4.470	2.24
Magnesium, µg/L	12	12	135.0	17,500	60,000	39,925
Manganese, µg/L	12	12	9.67	50.20	864	272.56
Mercury, µg/L	0	12	0.100	0.050	0.10	0.050
Molybdenum, µg/L	0	9	52.7	26.35	52.7	26.35
Nickel, µg/L	0	12	32.1	16.05	32.1	16.05
Silver, µg/L	0	12	0.333	0.1665	0.333	0.1665
Vanadium, µg/L	0	12	27.6	13.80	27.6	13.8
Zinc, µg/L	2	12	18.0	9.0	42.0	12.8

Notes:

CRL – certified reporting limit.

Data from: Data Summary Report, Jefferson Proving Ground, Madison, Indiana, January 1994 by Rust Environment and Infrastructure, Grand Junction, Colorado, Prepared Under DAAA15-90-D-0007.

Manganese was detected in the filtered sample collected from MW-11, which is screened in bedrock, at a concentration of 159 µg/L. This concentration exceeds the secondary MCL but is less than the mean background concentration of 272.6 µg/L for filtered samples. Manganese concentrations in filtered and unfiltered samples collected from wells screened in the overburden (wells MW-10, MW-RS3, MW-RS4, MW-RS5, MW-RS6, MW-RS7, and MW-RS8) and in a well screened in limestone and silty clay (MW-RS1) range from 19.4 µg/L – 2,690 µg/L. With the exception of the manganese concentration in MW-10 (19.4 µg/L), manganese concentrations exceed the secondary MCL.

Calcium was detected in all filtered and unfiltered samples. There is no MCL for calcium. Concentrations in unfiltered samples range from 74,100 µg/L – 172,000 µg/L. The mean background concentration for unfiltered samples is 96,041 µg/L. In unfiltered samples, calcium concentrations range from 71,200 µg/L – 343,000 µg/L. The mean background concentration for filtered samples is 96,858 µg/L.

Magnesium was detected in all filtered and unfiltered samples. There is no MCL for magnesium. Magnesium concentrations in unfiltered samples range from 28,100 µg/L – 70,600 µg/L. Three magnesium concentrations (70,600 µg/L in MW-RS1, 45,400 µg/L in MW-RS7 and 46,400 µg/L in MW-RS7's duplicate) exceed the mean background concentration for unfiltered samples (39,516 µg/L) but are within the same order of magnitude. Magnesium concentrations in filtered samples range from 30,700 µg/L – 202,700 µg/L. Four magnesium concentrations (including a normal and its duplicate sample results) exceed the mean background concentration for filtered samples (39,925 µg/L).

Molybdenum was detected in nine unfiltered samples collected from eight wells at concentrations that range from 6.06 µg/L – 22.2 µg/L. There is no MCL for molybdenum. Molybdenum was detected in six filtered samples, including the duplicate sample, at concentrations of 6.80 µg/L – 17.8 µg/L. All concentrations are below the mean background concentration of 26.4 µg/L for filtered and unfiltered samples.

Nickel was detected in six unfiltered samples, including the duplicate sample, at concentrations of 2.18 µg/L – 15.4 µg/L. There is no MCL for nickel. Nickel was not detected in any unfiltered sample collected from wells screened in limestone. Nickel was detected in seven of the eight filtered samples, including the duplicate sample and the only filtered sample collected from a well screened in limestone (MW-11). Nickel detections in filtered samples range from 2.09 µg/L – 13.2 µg/L. All nickel concentrations are below the mean background concentrations for filtered and unfiltered samples, 16.05 µg/L and 17.8 µg/L, respectively.

Vanadium was detected in six unfiltered samples (including the duplicate sample) at concentrations of 1.18 µg/L – 2.55 µg/L. There is no MCL for nickel. Vanadium was detected in four filtered samples (including the duplicate sample) at concentrations that range from 1.16 µg/L – 2.53 µg/L. All reported concentrations are below the mean background concentration of 13.8 µg/L for filtered and unfiltered samples.

6.5.1.4 Hardness and Total Dissolved Solids

Calculated hardness in unfiltered samples ranges from 172,000 µg/L – 626,000 µg/L (Table 6-9). In filtered samples (Table 6-10) hardness ranges from 324,000 µg/L – 1,690,000 µg/L. The highest calculated hardness was measured in the unfiltered sample collected from MW-11. An unfiltered sample was not collected from this well. Total dissolved solids concentrations were measured for unfiltered samples only. The highest concentration of total dissolved solids was measured in the sample from MW-11, the sample that had the highest calculated hardness. Excluding monitoring well MW-11, total dissolved solids concentrations range from 232,000 µg/L – 3,120,000 µg/L.

6.5.2 **Geology and Hydrology of Areas of Investigation**

6.5.2.1 Impact Field 5.3E

6.5.2.1.1 Geology

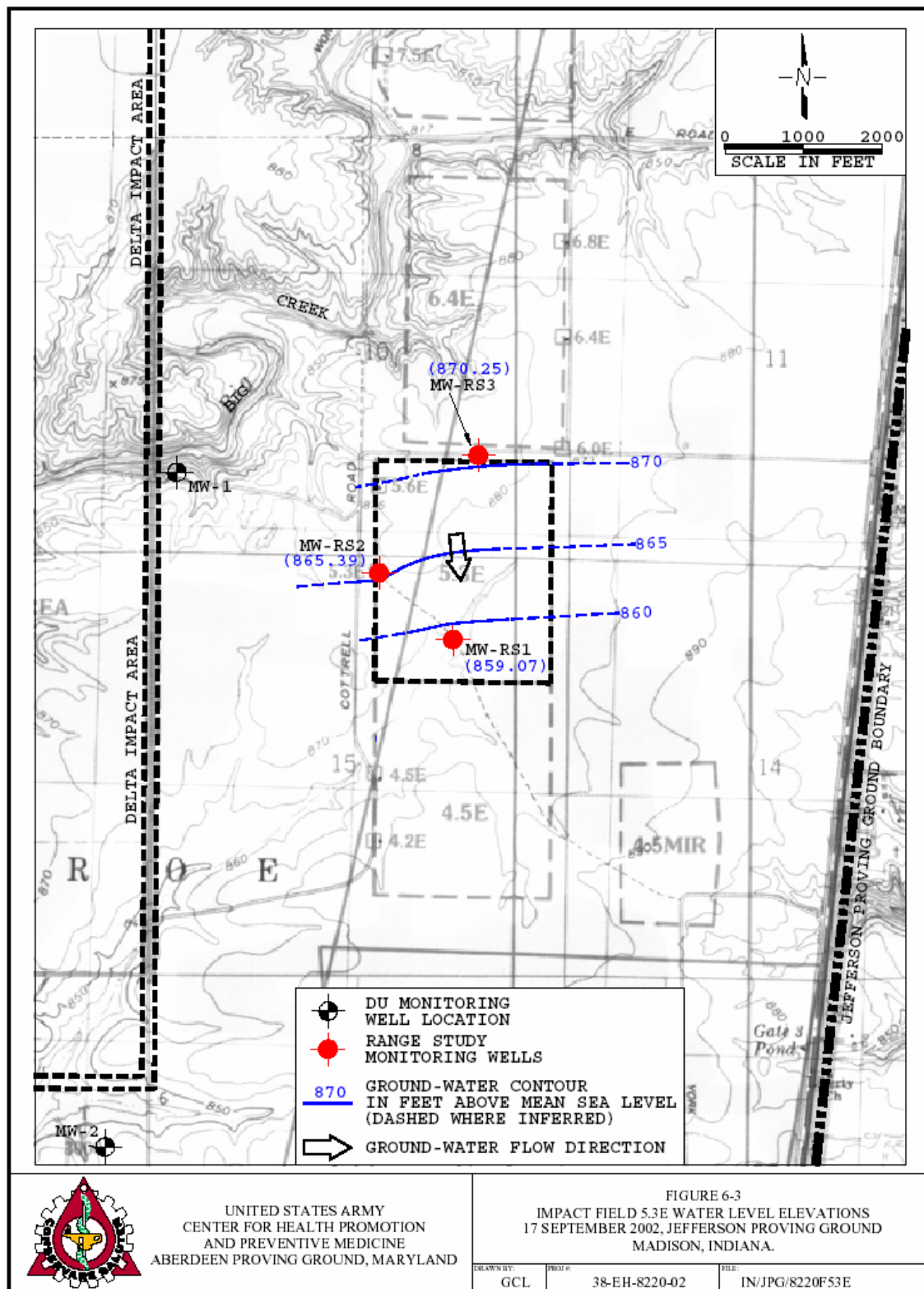
The majority of the ground surface across the Impact Field 5.3E was vegetated with grasses. Impact craters and UXO were sporadically located across the ground surface of this impact field. A generalized subsurface profile (Figure 6-2) was drawn to illustrate subsurface materials encountered during this range investigation. Boring logs in Appendix E were used to develop the subsurface profile. As shown on Figure 6-3, ground surface gently slopes from the north to the south toward the northwest side of an intermittent creek located in the southern half of the impact field. The slope direction changes on the southeast side of the unnamed intermittent stream. No flow was observed in the intermittent stream during field activities associated with this study.

Subsurface materials observed within the impact field are composed of fines, sand, and weathered limestone. Surface and near surface soils are primarily clayey or silty sands. The clayey and silty sands overlie a silty clay, which contains some fine sand. The silty clay overlies a weathered limestone. Boring MW-RS3 was terminated before encountering limestone (see boring log). Based on the location of weathered limestone in borings MW-RS1 and MW-RS2 and interpolation between these wells and MW-RS3, the location of limestone at MW-RS3 is approximated. It is also estimated that limestone like ground surface has a slope of approximately 1 percent to toward the south. A discontinuous layer (both horizontally and vertically) of silty clay is present within the limestone near MW-RS1. The thickness of the unconsolidated materials, which overlies the weathered limestone, decreases in the down-slope direction.

6.5.2.1.2 Hydrogeology

The open intervals of the wells extend across one or more types of subsurface material (see well logs in Appendix E). MW-RS1 is screened in weathered limestone and a clayey silt layer within the weathered limestone. The well's sand pack extends into the overlying clayey silt. MW-RS2 is screened in the weathered limestone, and the sand pack extends into the overlying material. More than 2 feet of bentonite is located below the top of the limestone and the top of the sand pack. The open interval in MW-RS3 extends across a silty clay.

FIGURE 6-3. IMPACT FIELD 5.3E WATER LEVEL ELEVATIONS



Ground-water levels were obtained from wells MW-RS1, MW-RS2, and MW-RS3 on 17 and 23 September 2002 (Table 6-5). A water level elevation contour map was constructed based on water level measurements made on 17 September 2002 (Figure 6-3). Based on water level data and site stratigraphy, the upper weathered limestone and the overburden function as one hydrologic unit. As shown on Figure 6-4, the estimated direction of ground-water flow is to the south. Ground-water elevations ranged from 858.80 feet msl (6.3 feet bgs) within the impact field to 869.78 (8.9 feet bgs) in the topographically higher area on the north side of the impact field. Monitoring well MW-RS3 is located hydraulically upgradient, and wells MW-RS1 and MW-RS2 are hydraulically downgradient and sidegradient of Impact Field 5.3E. Upgradient well MW-RS3 is probably hydraulically downgradient of Impact Field 6.4E. The average lateral hydraulic gradient, based on water level differences and horizontal differences between the wells installed at Impact Field 5.3 E is approximately 0.005 ft/ft.

6.5.2.2 Impact Field 3W

6.5.2.2.1 Geology

The majority of the ground surface across the Impact Field 3W was vegetated with grasses. Impact craters and UXO were sporadically located across the ground surface. Although field activities were conducted during a drought period, standing water and cattails were observed in some impact craters. A generalized subsurface profile, which illustrates subsurface materials at Impact Field 3W, is presented as Figure 6-5. Boring logs in Appendix E were used to develop the subsurface profile. As shown on Figure 6-5, ground surface is relatively flat but does slope slightly toward the northwest and the southeast from MW-RS7.

Subsurface materials are composed of fines and sand. Surface and near surface soils are primarily silty to clayey sands. The upper silty to clayey sand is underlain by a silty clay at well locations MW-RS4, MW-RS5, and MW-RS7, and the silty clay is underlain by clayey sand. At the northern most well location, MW-RS6, the silty clay is absent and silty to clayey sands extend the entire length of the boring.

6.5.2.2.2 Hydrogeology

Ground-water levels were obtained from wells MW-RS4, MW-RS5, MW-RS6, and MW-RS7 on 17 and 23 September 2002 (Table 6-5). A water level elevation contour map was constructed based on the 17 September water level measurements (Figure 6-6). As shown on Figure 6-6, the estimated direction of ground-water flow is to the southeast and the northwest. A ground-water divide is present at the impact field and the divide corresponds to the impact field's topographical high. Ground-water elevations range from 852.73 feet msl (6.47 feet bgs) at or near the divide, or topographical high, at MW-RS7 to 843.07 feet msl (8.11 feet bgs) on the north side of the impact field. Although monitoring well MW-RS7 is located within Impact Field 3W it is the hydraulically upgradient well. MW-RS4 and MW-6 are located downgradient, and wells MW-RS5 and MW-RS6 are hydraulically downgradient and sidegradient of the impact field.

FIGURE 6-4 Subsurface Profile Impact Field 3W

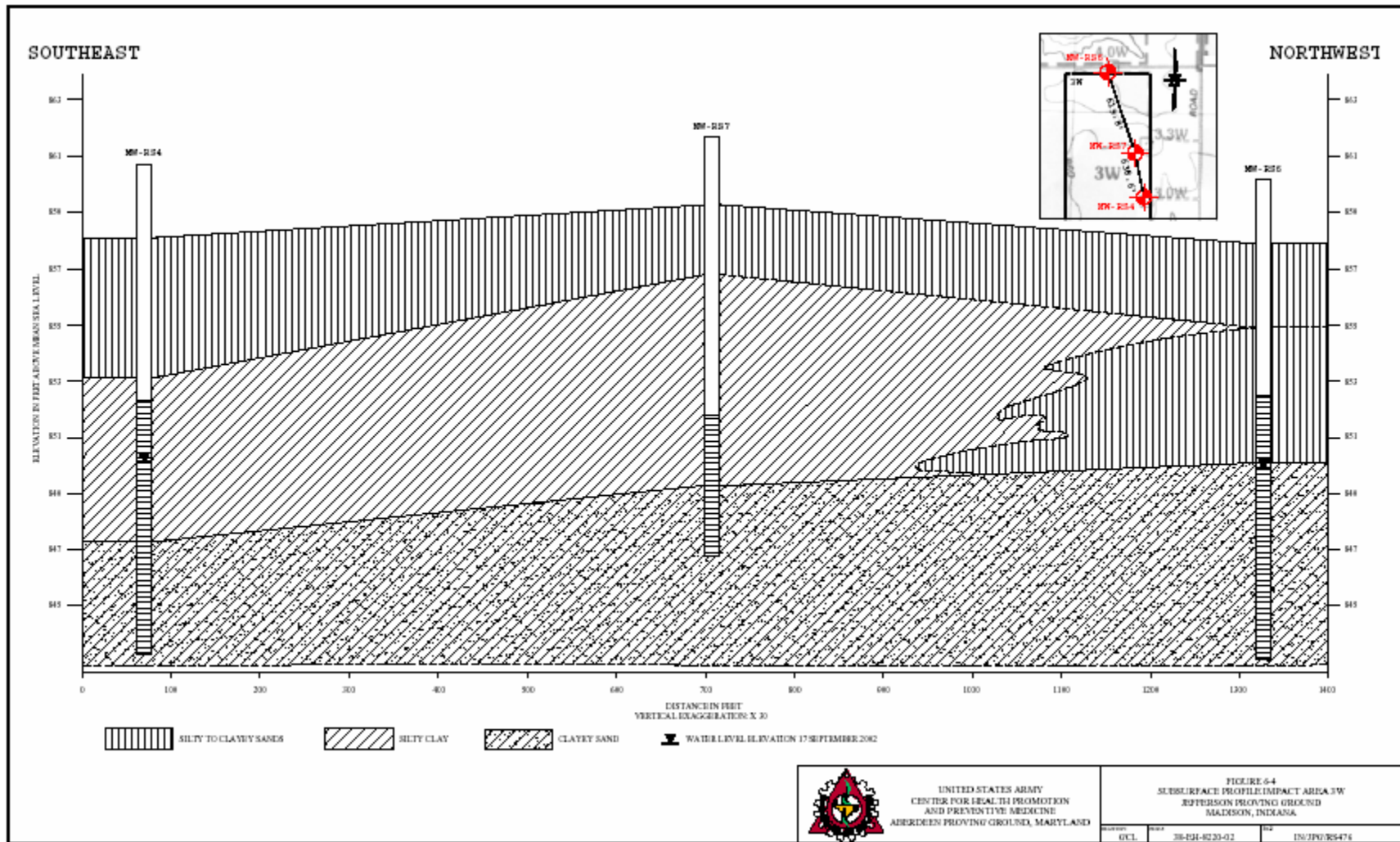


Figure 6-5 Impact Field 3W Water Level Elevations Contour Map

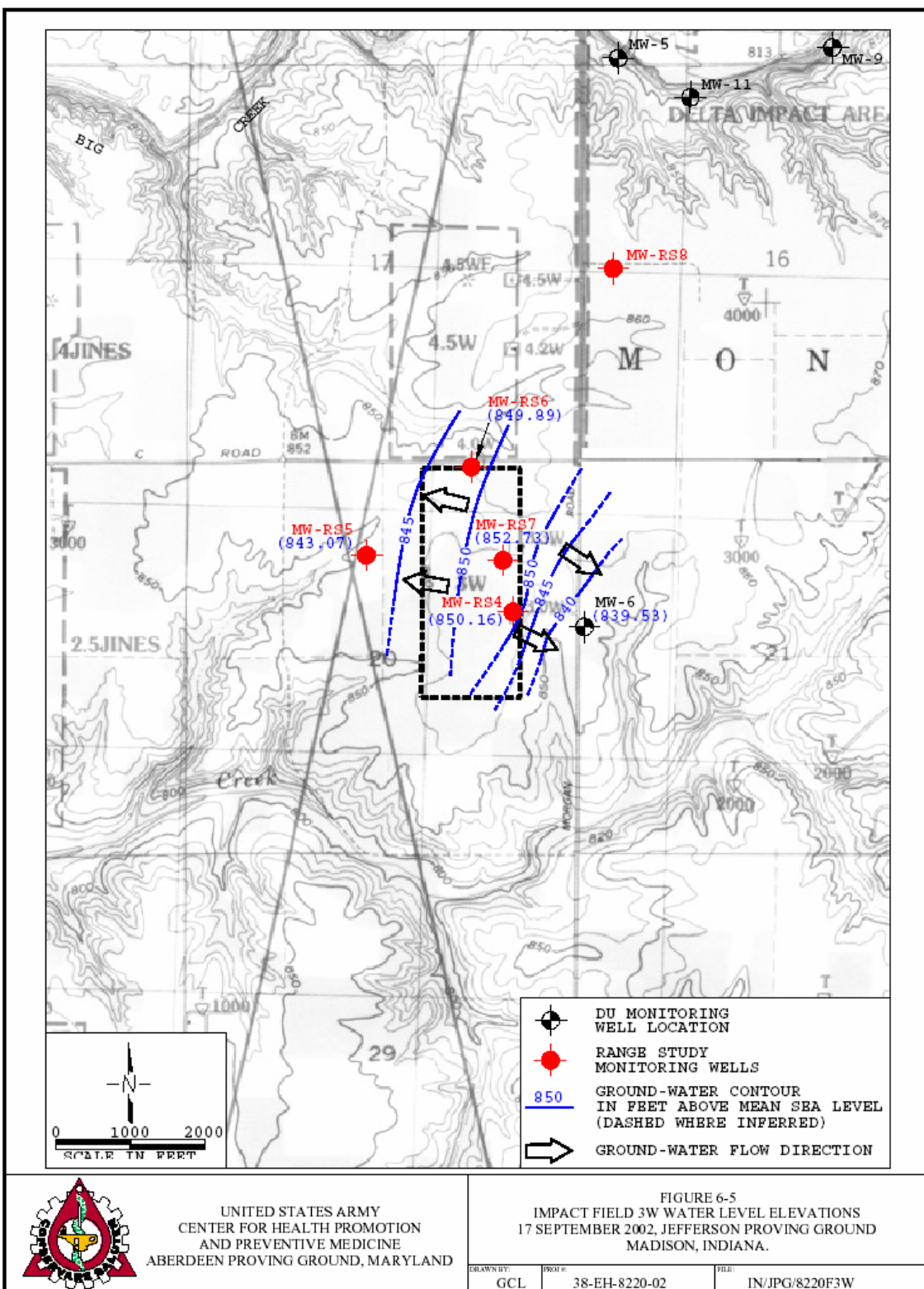
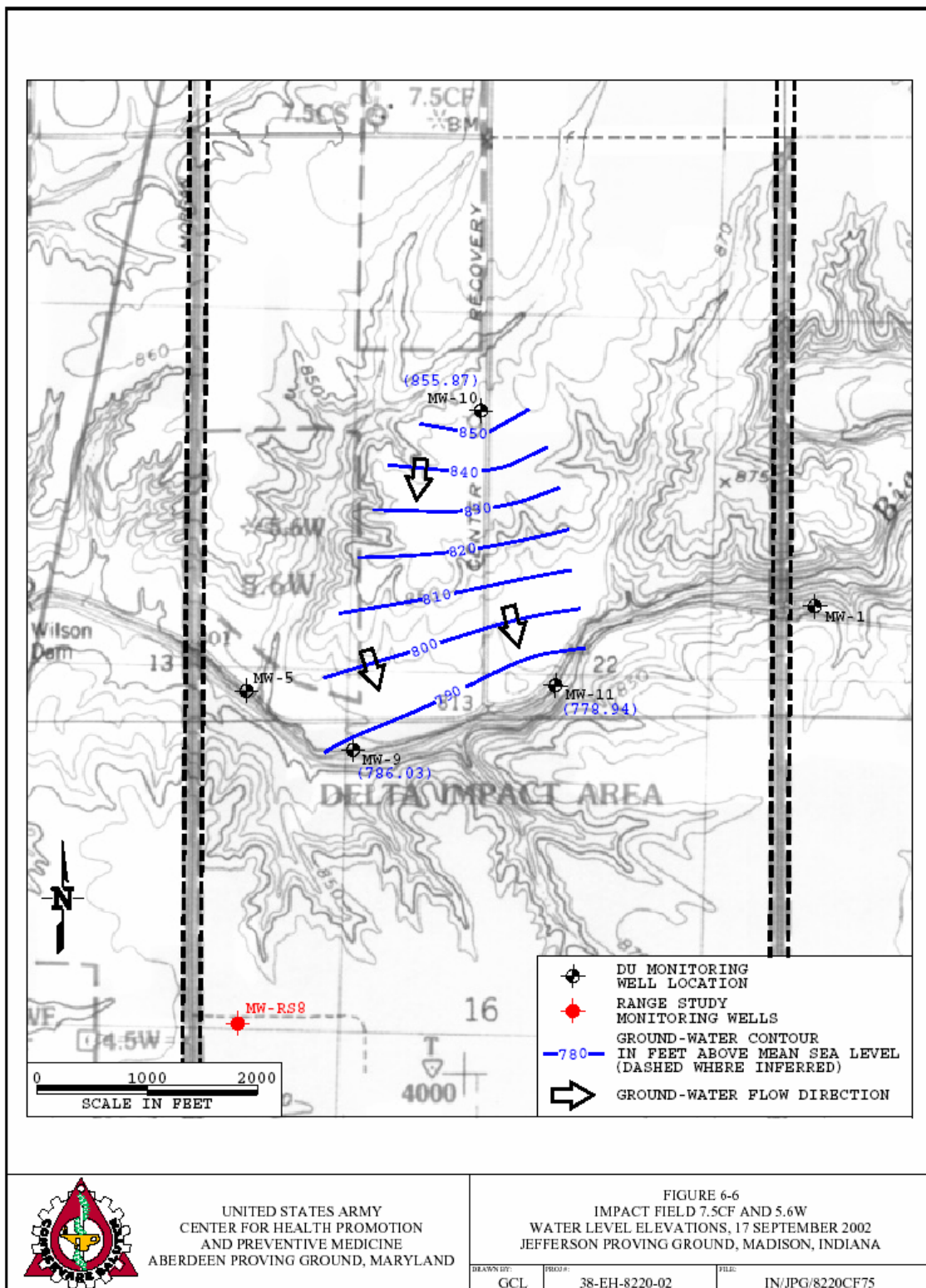


Figure 6-6 Impact Field 7.5CF and 5.6W Water Level Elevations



The average lateral hydraulic gradient to the southeast, based on water level and horizontal differences, is approximately 0.17 ft/ft. The average lateral hydraulic gradient on the northwest side of the ground-water divide is approximately 0.006 ft/ft.

6.5.2.3 Delta Impact Area South of Big Creek

6.5.2.3.1 Geology

Monitoring wells MW-1, MW-2, MW-5, and MW-6 were installed near the Delta Impact Area by others as part of the ERM program. The well borings were advanced to various depths that ranged to 40 feet bgs with an average depth of 32.6 feet. Limestone was encountered at well locations MW-1, MW-2, and MW-5 at 4.5 feet bgs (847.2 feet msl), 7.0 feet bgs (840.96 feet msl), and 5.6 feet bgs (795.97 feet msl), respectively. The overburden at each of these locations was described as silty clay. MW-6 was drilled to 40 feet bgs (818.44 feet msl), and limestone was not encountered in the boring. The subsurface material at MW-6 was described as a silty clay. MW-RS8 was advanced to 15.7 feet bgs (848.3 feet msl) and like MW-6 limestone was not encountered. The subsurface material at MW-RS8 was described as a silty clay with sands. Additional data points are needed in the Delta Impact Area South of Big Creek to construct a meaningful subsurface profile.

6.5.2.3.2 Hydrogeology

Water levels in the area range from 786.85 feet msl at MW-5 to 854.42 feet msl at MW-RS8. Monitoring wells near and within the Delta Impact Area south of Big Creek are too widely spaced to construct a meaningful ground-water elevation contour map. Based on water level data collected from MW-6 and wells in Impact Field 3W, MW-6 is located hydraulically crossgradient (Figure 6-6) of the Delta Impact Area. Monitoring well MW-2 is located near the southeast channel of a tributary of Middle Fork Creek that cuts across the southeast corner of the Delta Impact Area. Near incised surface drainages at JPG, ground water in shallow bedrock tends to discharge to surface stream (see Section 6.2.3.2). Based on this, shallow ground water in the MW-2 area southeast of the unnamed tributary probably has a different flow direction than ground water northwest of the creek.

6.5.2.4 Delta Impact Area North of Big Creek

6.5.2.4.1 Geology

Monitoring wells MW-9, MW-10, and MW-11 were installed within the Delta Impact Area north of Big Creek (Figure 6-6). The boring advanced for monitoring well MW-10 is topographically more than 40 feet higher than MW-9 and MW-11. The subsurface material at boring MW-10 was described as a clayey to sandy silt. The boring was terminated at a depth of 41.3 feet bgs (819.5 feet msl). Bedrock, described as limestone and shale, was encountered at MW-9 at 3.7 feet bgs (815.9 feet msl) and at MW-11 at 2 feet bgs (807.4 feet msl). The overburden at MW-9 and MW-11 is clayey silt.

6.5.2.4.2 Hydrogeology

Ground-water levels were obtained from wells MW-9, MW-10, and MW-11 on 17 September 2002 (Table 6-5). Water levels were not measured on 23 September 2002 because water levels had not recovered to static conditions after sampling activities. Monitoring wells MW-9 and MW-11 are screened in bedrock and MW-10 is screened in a sandy to clayey silt. Measured ground-water elevations are below the top of screens in MW-9 and MW-11, and the open intervals in both wells is sealed below the contact between the overburden and the bedrock.

6.6 PROBLEMS ENCOUNTERED AND DEVIATIONS FROM THE QAPP

6.6.1 Well Installations

Three wells, instead of the four wells specified in the QAPP, were installed around Impact Field 5.3E. The reasons only three wells were installed are discussed in Section 6.4.1 of this report.

6.6.2 Sample Identification

The DLS laboratory report for total dissolved solid analyses lists one sample identification as MW-S. The correct sample identification is MW-5.

6.6.3 Data Quality Indicators

6.6.3.1 Duplicate Samples

The QAPP called for duplicate samples equal to at least 5 percent of the number of normal ground-water samples. One split sample, labeled as MW-RS9, more than 5 percent, was collected from MW-RS7. The results for the normal and duplicate samples indicate precision as measured by the relative percent difference (RPD). Only metals were detected in samples, nine metals in MW-RS7 and eight metals in MW-RS9. Among the detected metals, the RPDs ranged from 1 - 133. The RPD was less than the objective of 50 (Section 7.3.7 of the QAPP) for all but 2 of the calculated RPDs. The two high RPDs (68 & 133) are skewed by nondetects. Since the RPD is intimately linked to the magnitude of the results, it works best when detectable levels of contaminants are present. Table 6-12 shows RPD results for metals.

TABLE 6-12 RELATIVE PERCENT DIFFERENCES

Metal	A	B	(A-B)	2(A-B)	(A+B)	RPD
Antimony	<2	<2	0	0	4	0
Arsenic	2.02	<1	1.02	2.04	3.02	68
Barium	74	73.8	0.2	0.4	147.8	0.3
Cadmium	<1	<1	0	0	2	0
Calcium	73.1	74.7	1.6	3.2	147.8	2
Calculated Hardness	369	378	9	18	747	2
Chromium	<2	<2	0	0	4	0
Copper	2.06	<2	0.06	0.12	4.06	3
Lead	<2	<2	0	0	4	0
Magnesium	45.4	46.4	1	2	91.8	2
Manganese	799	800	1	2	1599	0.1
Mercury	<0.2	<0.2	0	0	0.4	0
Molybdenum	17.9	17.7	0.2	0.4	35.6	1
Nickel	3.34	3.19	0.15	0.3	6.53	5
Silver	<1	<1	0	2	2	0
Vanadium	1.92	2.02	0.1	0.2	3.94	5
Zinc	<0.02	<0.1	0.08	0.16	0.12	133

6.6.3.2 Equipment Rinsate Blanks

Most samples were collected directly from the discharge tubing of a pump. Tubing was dedicated to a single well. One equipment rinsate blank was collected by pumping distilled water through a peristaltic pump fitted with new tubing. The rinsate blank was analyzed for total metals, perchlorate, and explosives. Calcium was the only analyte detected in the rinsate blank. A rinsate blank was not collected from a bailer used.

6.6.3.3 Representativeness

Representativeness is the degree to which data accurately characterize a population, parameter variations at a sampling point, a process condition, or an environmental condition. The degree of representativeness is dependant on the thoroughness and proper design of the QAPP and Sampling Plans (SP) and adherence to its prescribed procedures, especially regarding the assumptions made during the development and the statistical soundness of the sampling design. Representativeness in this ground-water investigation was maintained through the careful application of industry accepted procedures in the sampling as defined in the JPG QAPP and with the use of quality assurance (QA) audits.

6.6.3.4 Comparability

Comparability is an expression of the confidence with which one data set can be compared with another. Comparability is also dependent on similar QA objectives. There are no numerical values that can be placed on this concept. This involves a subjective review and evaluation process, and the use of the appropriate field and analytical methodologies.

6.6.3.5 Completeness

Field completeness is based on the number of samples collected versus the number of samples planned. Fifteen wells were planned to be sampled for metals, perchlorate, explosives, hardness, and total dissolved solids. Completeness for sample analyses is summarized in Table 6-13. Ninety percent completeness was the standard established by the QAPP and this standard was met for explosives and perchlorate samples. Due to slow recovery rates at several wells (MW-6, MW-9, and MW-11) the full suite of samples could not be collected, which lowered the percent complete for unfiltered and filtered metals and total dissolved solids analyses. Further adding to the low percentage for filtered metals was a field decision not to collect samples for filtered metals if the ground water was below 5 Nephelometric Turbidity Units (NTU).

TABLE 6-13 SAMPLE COMPLETENESS

Analyte	Number of Samples Planned for Collections	Number of Samples Collected	Percent Complete
Explosives	15	15	100
Metals (Unfiltered)	15	12	80
Metals (Filtered)	15	7	47
Perchlorate	15	14	93
Total Dissolved Solids	15	13	87

6.6.4 **Analytical QC**

Field analysis of pH, specific conductance, dissolved oxygen, and temperature was made at each well prior to collecting the samples. Monitoring wells MW-6 and MW-9 were purged dry and had very slow recovery rates which limited the number of field parameters that could be collected. The primary purpose of these analyses was to determine when the wells were sufficiently purged to provide samples representative of the ground water.

6.7 SUMMARY

Eight monitoring wells (three in Impact Field 5.3 E, four in Impact Field 3W, and one in the Delta Impact Area) were installed in the surficial aquifer underlying the study area. The wells were installed to collect ground-water quality and ground-water elevation data. In order to better define ground-water conditions in the study area, ground-water quality and elevation data were also collected from seven pre-existing wells. Based on ground-water elevation data, shallow ground water in the study area appears to follow topography.

Ground-water samples were collected from all wells and were analyzed for one or a combination of the following: 15 explosive compounds (explosives and their degradation compounds), 14 metals, DU, perchlorate, hardness, and total dissolved solids. Due to low recovery rates in some of the pre-existing wells, a full suite of sample analysis could not be completed for each well. All wells were sampled and the samples were analyzed for explosive compounds. Fourteen wells were sampled for perchlorate. Metals samples from 12 wells were collected and analyzed. Samples collected from 13 wells were also analyzed for hardness and dissolved solids.

No explosive compounds or perchlorate were detected in any ground-water sample. Antimony, cadmium, chromium, mercury, silver, and zinc were not detected in any sample. Arsenic, barium, copper, lead, and total uranium were detected in samples collected from one or more wells at concentrations below their respective primary or secondary MCL. Manganese was detected in the majority of samples collected from wells screened in the overburden at concentrations above the secondary MCL and above the mean background concentration. Manganese concentrations in samples collected from wells screened in bedrock were below the secondary MCL. Calcium concentrations exceed the mean background concentration; there is no MCL for calcium. The high concentrations of manganese and calcium in ground water are most likely a result of the parent material of the overburden in the area. Other metals detected in ground water are molybdenum, nickel, and vanadium. Reported concentrations of molybdenum, nickel, and vanadium are below their respective background concentrations; there are no MCLs for these metals.

6.8 CONCLUSIONS

Ground-water sample results show no evidence of ground-water contamination from the past use of munitions or the presence of UXO in the study area.

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